battery charge/refresh station (2)

construction, adjustment and practical use

Last month's article, which describes the features and circuit diagram of the battery charge/refresh station, clearly suggests that completing such a project, with peak charging currents of up to 8 A, is a bit more demanding than for a device with fewer automatic features and relatively lower performance. The construction information given here is thus especially important if you wish to obtain a good result. In addition to descriptions of the construction and the microprocessor-controlled, menu-driven alignment procedures, you will find many helpful, practical tips regarding battery charging and maintenance.

Design by N. Bechtloff & G. Brenner
(Conrad Technology Center, CTC)

Before starting, you should understand that the battery charge/refresh station is not a suitable project for beginners. In addition to the relatively complex electronics and several alignment procedures, the relatively high output current (8 A peak maximum!) of this high-performance charger can result in significant damage in case of a short circuit. However, if you have already successfully built a high-power amplifier or a laboratory power supply, you should not have any difficulty with this power project, as long as you work carefully.

CONSTRUCTION HINTS

The charge/refresh station is built using two single-sided printed circuit boards, as shown in **Figures 4 and 5**. These are supplied as a set and thus have a single order number in the components list. One disadvantage of using single-sided boards is a relatively large number of wire jumpers. It is best to begin by inserting these jumpers, and to carefully check your results against the component layout diagram to be sure that there are in fact seven on the smaller board and eight on the larger one. The pins for jumper JP1 can best be placed on the solder side of the front panel board, so that the jumper is accessible after the LCD module has been mounted on the component side. IC4 must be mounted flat on the larger board, so that its case does not push against the front panel. Pushbutton S3, switch S1 and LED D6 should be provisionally connected to the circuit board to start with. After the unit has been tested and aligned, they can be mounted in their final positions on the front panel and connected to the circuit board using light-duty flexible wire. The socket for the microcontroller can initially be left empty, and the LCD module need not be plugged into the socket strips right away, since neither of these components is necessary for the first two alignment procedures (fan voltage and temperature monitoring).

The temperature monitoring circuitry is optional and need not necessarily be installed. If you do not wish to monitor the temperature of the heatsink or the battery, you can eliminate not only the NTC sensor but also resistors R54, R56, R80 and R82 (R81 must always be used). The NTC sensor should have a cold resistance between 500 and 1000 Ω. The shutoff temperature of the circuit is set by selecting the value of R80, as described under 'Alignment'.

The use of a CPU heatsink with a built-in fan instead of a plain heatsink is an unusual feature. In principle, any standard CPU cooler can be used. What is important is that the transistors are mounted insulated from the heatsink, preferably using ceramic insulation washers with heat conducting paste on both sides. The holes for the fixing screws should be drilled to 2.5 or 2.7 mm and tapped for an M3 thread. For safety, check the assembly with an ohmmeter before installing the heatsink, to be sure that the transistors are truly insulated from the heatsink. Since the transformer can deliver a very high current (not to mention a battery pack), any short circuit could have unpleasant consequences.

When mounting the boards in the enclosure, take care that the cooling air flow is not obstructed. The metal panel that fits into the rear of the enclosure should have a suitably-sized opening for the fan. Additional ventilation slots can be made in the enclosure to improve the cooling.

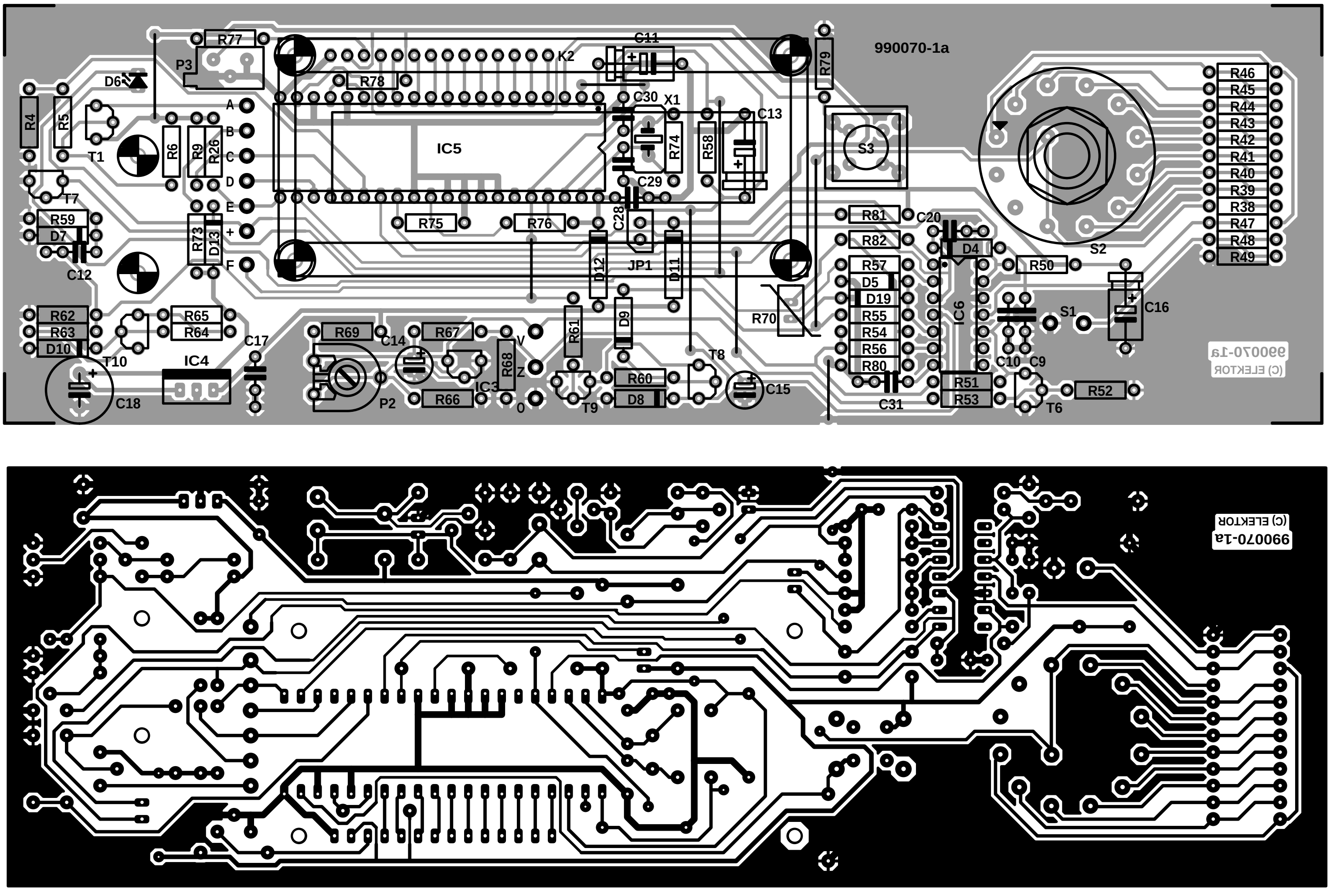
Determining the value of the series fan resistor R72 is described under 'Alignment'.

The photos show the fully-populated boards and how they are fitted into the enclosure. When connecting the transformer to the mains cable sockets, take particular care that the insulation is adequate. All components that carry mains voltage must be fully insulated against contact with the user.

The transformer usually has four secondary leads. The leads for the two 'outer' ends of the winding are grey and red, while the yellow and blue leads can be connected together to form the centre tap.

Make the ten connections between the two circuit boards using flexible low-duty wire, but use heavier-duty wire for the earth connection (around the same diameter as used for the mains connection). In the bottom of the enclosure, drill suitable holes for attaching the smaller circuit board and fixing the ring-core transformer.

Figure 4. The larger circuit board with the microcontroller, controls and display is located behind the front panel.



COMPONENTS LIST

Resistors:
R1,R25,R67,R75,R76,R82 = 100kΩ
R2,R3,R37 = 0Ω1 5W
R4,R21,R52,R79,R81 = 22kΩ
R5,R9,R14,R18,R61,R66,R71 = 10kΩ
R6,R78 = 47kΩ
R7 = 33kΩ2 1%
R8 = 15kΩ4 1%
R10 = 750Ω 1%
R11 = 1MΩ 1%
R12 = 9kΩ09 1%
R13 = 215kΩ 1%
R15,R16,R33,R34 = 100Ω
R17,R53,R56,R77 = 4kΩ7
R19,R20 = 3kΩ3
R22,R64 = 1kΩ
R23 = 487kΩ 1%
R24 = 33kΩ
R26,R50,R59 = 220kΩ
R27 = 3kΩ83 1%
R28 = 237Ω 1%
R29,R62 = 15kΩ
R30,R68 = 2kΩ2
R31 = 390Ω
R32 = 27kΩ
R35,R36 = 0Ω27 5W
R38-R46 = 20kΩ 1%
R47,R48 = 10kΩ 1%
R49 = 3kΩ32 1%
R51 = 178kΩ 1%
R54 = 5kΩ11 1%
R55 = 470kΩ
R57 = 5kΩ6
R58 = 150kΩ
R60 = 1MΩ
R63 = 1kΩ8
R65 = 1kΩ2
R69 = 470Ω
R70 = NTC, 500Ω *
R72 = 27Ω 2W *
R73 = 220Ω
R74 = 10MΩ
R80 = 220Ω *
R83 = VDR S10K275 (Siemens)
P1 = 100Ω preset H
P2 = 1kΩ preset H
P3 = 1kΩ preset V

Capacitors:
C1,C8,C12,C17,C20,C21,C23,C24,C25,
C28,C31 = 100nF ceramic
C2,C3 = 1μF 16V tantalum bead
C4 = 1nF raster 5mm
C5 = 10nF
C6,C10 = 22nF
C7 = 22nF
C9 = 1nF
C11 = 1μF 16V
C13,C19 = 47μF 16V
C14,C15 = 10μF 63V radial
C16,C26 = 10μF 63V
C18,C27 = 220μF 35V radial
C19 = 47μF 16V radial
C22 = 22μF 35V
C29,C30 = 22pF

Semiconductors:
D1-D4,D7,D9,D11,D12,D13,D15,D16,
D17,D19 = 1N4148
D5 = BAT85
D6 = LED high efficiency
D8 = zener diode 6V8, 400mW
D10 = zener diode 5V6, 400mW
D14,D18 = 1N4001
T1,T3,T10 = BC557B
T2,T9 = BC547B
T4,T5 = BUZ11
T6,T7 = BC548C
T8 = BF245B or BF 256B
THR1,THR2 = TIC116A or BT151-500R
IC1 = LM324 (DIL14)
IC2,IC6 = LM339 (DIL14)
IC3 = TL431CLP
IC4 = 7806
IC5 = 68HC05C4 (Harris), Conrad
Electronics order code 692265

Miscellaneous:
JP1 = jumper
K1 = mains appliance socket with
integral fuse 630 mAT and mains
switch
K2 = 14-way pinheader
K3 = 3-way PCB terminal block
K4,K5 = 2-way PCB terminal block
S1 = on/off rocker switch
S2 = rotary switch, 12 contacts, 1 pole,
PCB mount
S3 = pushbutton, 1 make contact
F1 = POLYFUSE 1A6 (Polyswitch,
Conrad Electronics o/n 53 60 83)
Tr1 = toroidal transformer 2 x 18V 3.33A
X1 = 4MHz quartz crystal
F2,F3 = 6.3AT with PCB mount holder
and cap
CPU ventilator
Case: Bopla Lab 223 mm x 72 mm x
199 mm (Conrad Electronics o/n 52 33
48) with front panels (Conrad
Electronics 52 33 72)
LCD-Module 1 line, 16 characters
(Sharp LM16155)
4 off TO220 mica washer with plastic
bush
2 off wander socket dia. 4mm
PCB, order code **990070-1** (see
Readers Services page)
*) see text

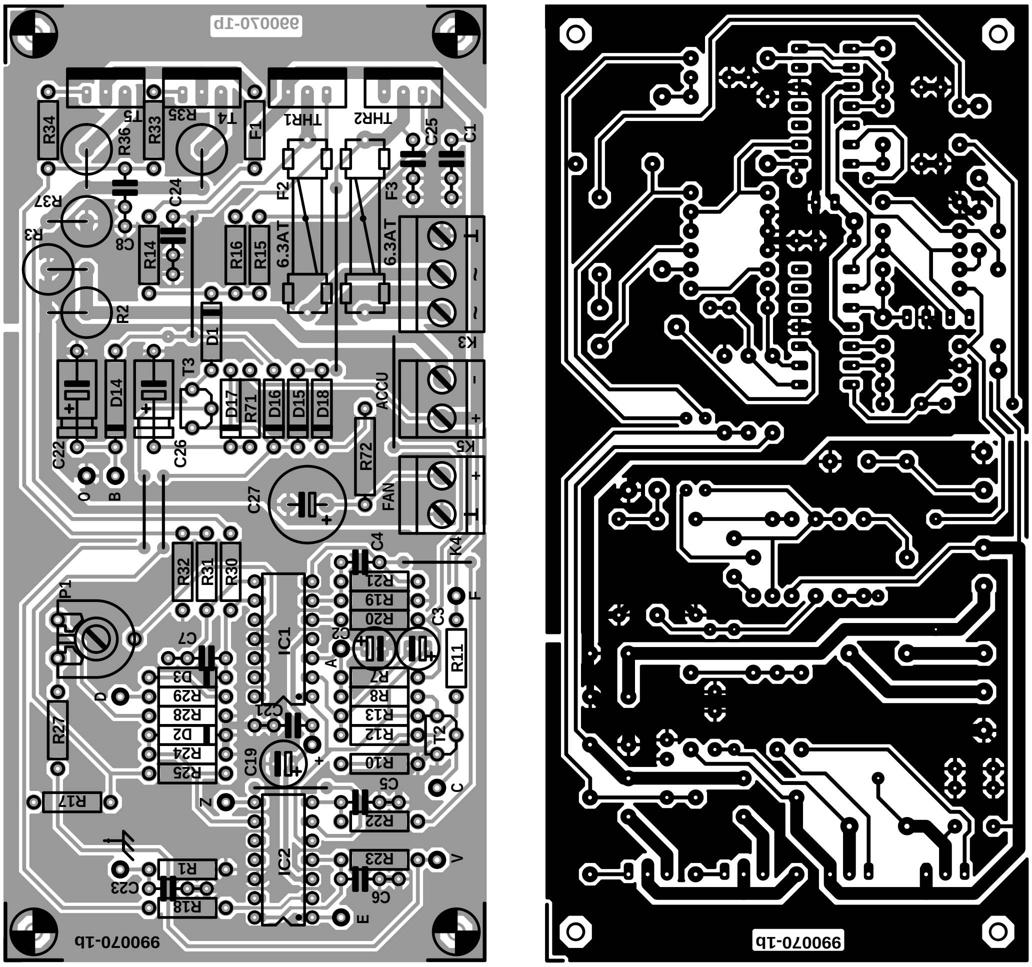


Figure 5. The smaller circuit board with the power components of the charger circuit.

Mounting the larger circuit board at the front of the enclosure is relatively simple — just slide it into the proper slot in the lower half of the enclosure.

ALIGNMENT

The first task is to match R72 to the actual CPU cooler used. The controller need not be installed for this. Connect the fan to K4 and measure the voltage across K4. If this differs from the nominal fan operating voltage (usually 12 V) by more than 1 V, the value of R72 must be appropriately modified. For testing, you can briefly use standard 1/3-W resistors if you do not have a suitable stock of 2-W or 5-W resistors. The fastest way to determine the correct resistance is to first solder in a resistor with too high a value (such as 47 Ω) and then hold a second resistor by hand 'across' this resistor (in parallel) while observing the voltage at K4. Start with a relatively high value for the second resistor, and then try successively lower values until the correct fan voltage is obtained. Next measure the effective resistance of the parallel resistors, and then solder a 2-W resistor with this value in place on the circuit board.

The controller is also not needed for the alignment of the **temperature monitoring circuitry**. First bring the unmounted NTC sensor (with a cold resistance of 500 to 1000 Ω) to the desired cutoff temperature, and measure its resistance at this temperature. Choose a resistor with the same value for R80, and mount it on the board. Mount the NTC sensor where the temperature is to be monitored, such as on the transformer or the heatsink. If you wish to monitor the battery temperature during charging, the NTC sensor must be fastened to the battery (using an elastic or sticky tape, for example), and the cutoff temperature should be around 45°C. If the transformer or heatsink is monitored, the cutoff temperature can be 60° to 90° C.

For the remaining alignments, all components must be installed, including the controller and the LCD module. To start the microcontroller-controlled alignment procedures, put S1 in the 'NiCd' position (closed), set S2 to position '6', install jumper JP1 and switch on the charge/refresh unit. Now adjust P3 (display contrast) for the best legibility. The display will read 'START SELFTEST'. Remove JP1.

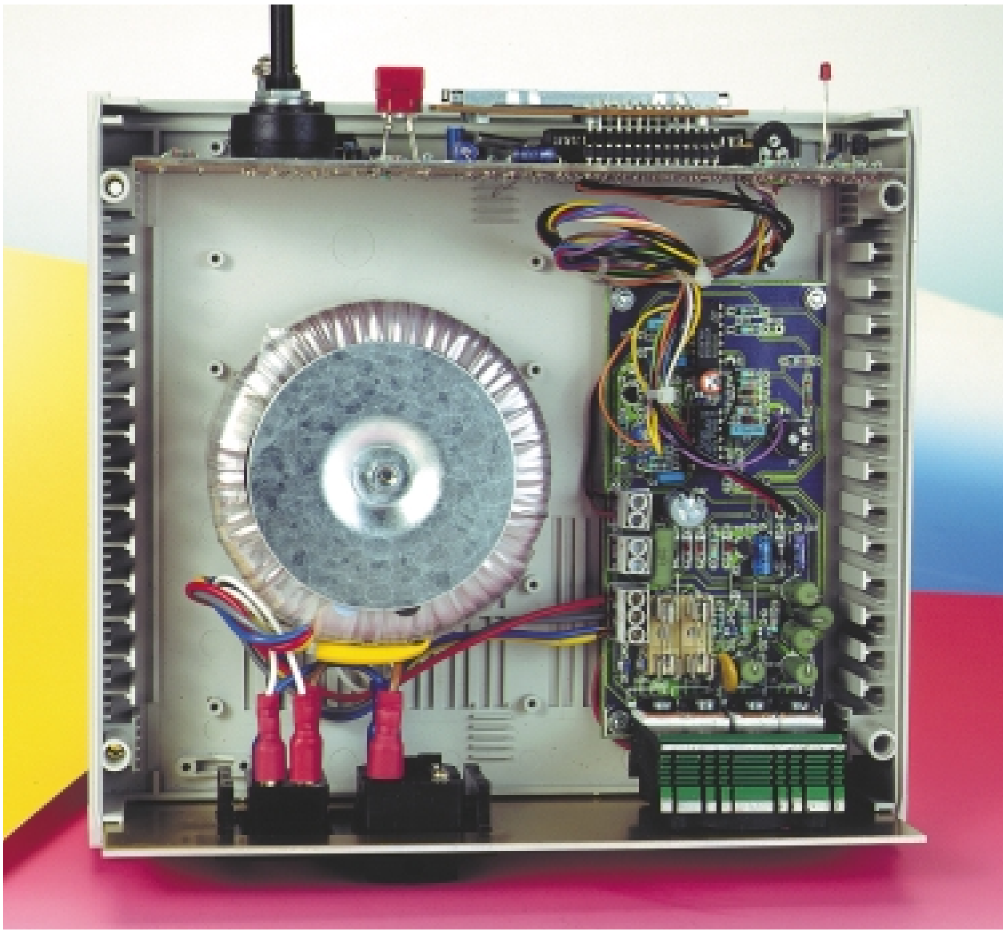


Figure 6. Top view of the prototype.

A multimeter with a current range of 3 to 10 A d.c. is needed for the following alignments. Connect it between the positive and negative terminals of K5, where it will measure the output current of the battery charger flowing through the meter. Since the current is pulsed, true-RMS meters will give somewhat different readings than ordinary meters, but the differences are slight. Adjust the charge and discharge currents as follows:

1. Press S3. The display will read 'CHARGE = 3 A MAX'. Adjust the indicated value of the current to 3 A using P2.

2. Press S3 again. The display will read

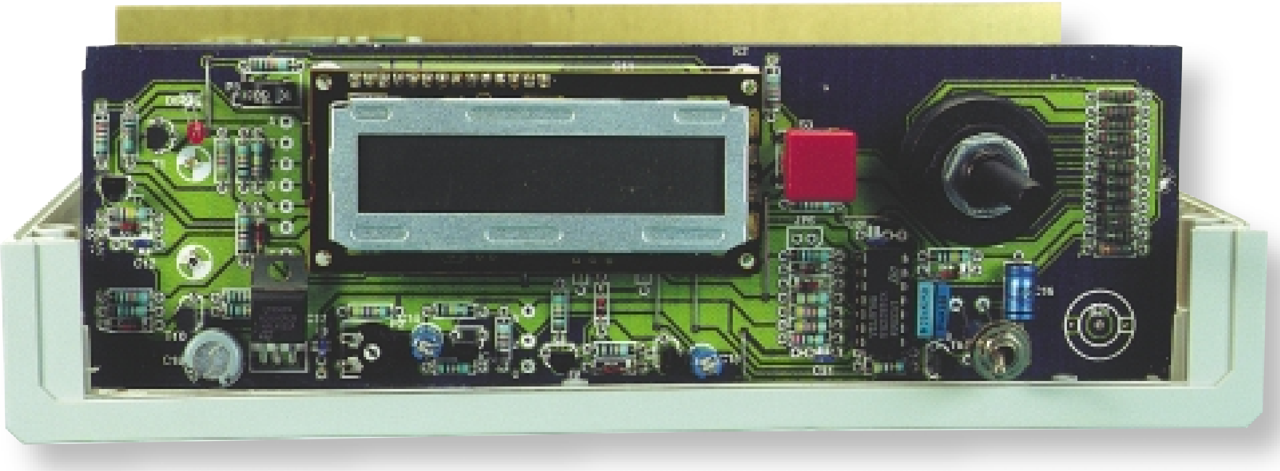


Figure 7. Front view of the prototype.

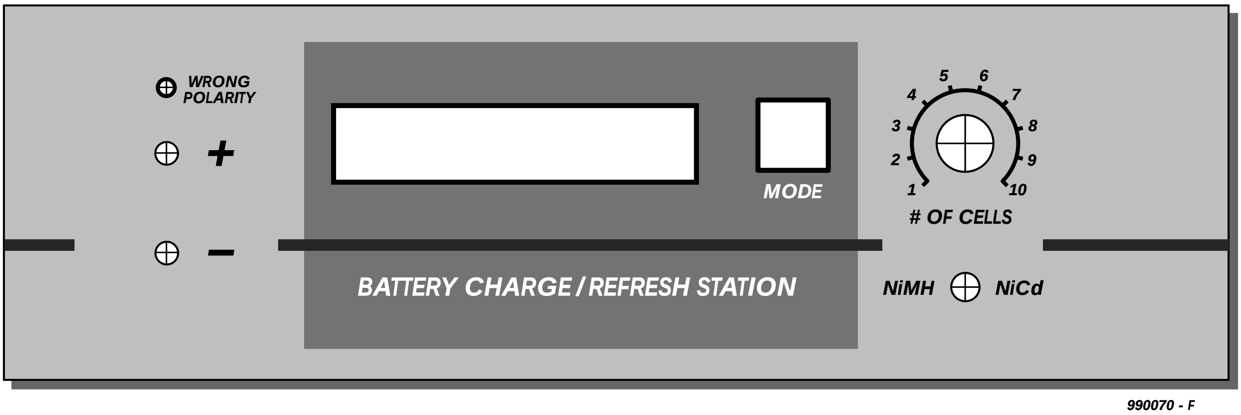


Figure 8. Suggested front panel layout (reproduced at 75% of true size).

'CHARGE = 2 A MID'. The indicated value should remain at 3 A however.

3. Press S3 again. The display will read 'CHARGE = 1 A MIN'. The indicated value should be within 10% of 1 A. Disconnect the meter.
4. Press S3 again. The display will read 'ADJUST 1.800 A'. Connect a **fully-charged** battery containing 4 to 8 cells together with an ammeter in series with the battery (between the positive terminal of K5 and the positive terminal of the battery). Adjust P1 for a charging current between 1.78 and 1.82 A. Disconnect the meter and battery.
5. Press S3 again. The display will read 'OVER-VOLTAGE'. Set S2 to position '**8**' (8 cells). The display will read 'IN:xxxx EMP:1220'. The value 'xxxx' must be greater than 1200. Next put S1 in the 'NiMH' position (open). Now either the value of 'xxxx' must be greater than 1800, or the display must read 'OVER-VOLTAGE' (the displayed values depend on the no-load voltage of the transformer).
6. Next, short the positive and negative terminals of K5 together to produce an intentional short circuit. The displayed value must be less than 10, and the polarity error indicator (LED D6, 'wrong polarity') must light. Remove the short circuit.
7. Press S3 again. The charger will now be in the normal operating mode, and the display will read 'NO ACCU TO SERVE' ('accu' = battery), since no battery is connected.

OPERATION

Switch on the charge/refresh unit with no battery connected. It will display 'NO ACCU TO SERVE', which indicates that it is ready to use. As long as no battery is connected, pressing S3 has no effect. Now select the battery type with S1 and the number of cells with S2 (1 to 10), and then connect a battery or battery pack. As soon as the message 'ADJUST: CHARGE' appears, you have five seconds to press S3 to select a different program (see the 'Program modes' box). If S3 is not pressed within five seconds, the CHARGE program is automatically started. If on the other hand S3 is pressed, a new program is selected each time it is pressed, in the sequence CYCLE, ALIVE (= refresh), CHARGE..... If S3 is not pressed again within five seconds after the last time it was pressed, the indicated program is started and charging is activated, as indicated by the message 'START CHARGING'. After an additional 15 seconds, the loaded capacity is indicated by the message 'CCAP = xxmAh' (for example, 'CCAP = 1.8mAh', where 'CCAP' stands for 'charged capacity').

A number of displays can be brought up during the charging process by pressing the function button. First the selected program mode is displayed for about two seconds ('CHARGE MODE', 'CYCLE MODE' or 'ALIVE MODE'), following which the discharge capacity DCAP is displayed for about five seconds if charging is taking place (for example, 'DCAP = 0.0mAh'), and then the charged capacity CCAP is displayed. For discharging, the display sequence after the pushbutton is pressed is different; after the mode display, CCAP is displayed followed by DCAP. If no measurement data are available, such as for DCAP when the battery is being charged in the CHARGE program, the value '0.0' is displayed.

The charging process ends when the battery no longer accepts any charge. In the CYCLE and ALIVE programs, the discharge process starts at this time, as indicated by the message 'START DISCHARGE'; otherwise the message 'CHARGER FINISHED' indicates that the battery may be discon-

Capacities

The measure of the status of a battery is its capacity, which means the total current that can be drawn from it, expressed in ampère-hours (Ah) or milliampère-hours (mAh). There is a relatively strong dependence between the capacity and the level of the discharge current. The lower the discharge current, the lower the losses during discharging, and thus the higher the capacity. When buying batteries, you should pay attention to the discharge current at which the capacity is specified by the manufacturer. In this regard, the concept 'C-rate' is often used, in which the current level (in A or mA) is specified as a fraction of the rated capacity (in Ah or mAh). For example, a capacity of 1 Ah at C/10 (0.1 C) means that the capacity was measured at a discharge current of 100 mA. If a different manufacturer specifies the same capacity at a higher C rate (such as C/3 = 0.33 C), the latter battery is in principle better. In this example, if a capacity of 1 Ah is achieved at a discharge current of 333 mA, you can rest assured that the capacity at 100 mA will be higher.

You should not overlook the fact that this high-performance charger works with a high discharge current (initially 1.5 A, dropping to 0.5 A). The measured capacity under these conditions applies to high-current loading of the battery and will thus always be somewhat lower than the value specified by the manufacturer, except for large and/or very high-performance batteries.

The amount of current accepted by the battery while it is being charged does not give any particular indication of the capacity of the battery. It is always higher than the battery capacity, since part of the charging current is lost in the form of heat, increasingly as the charging process nears completion.

nected. The CCAP and DCAP values can also be called up for display by pressing the function button after charging is completed, just as during charging or discharging. Press the pushbutton to cycle through the displays.

If the charging process cannot be completed successfully, due to a defective or unsuitable battery, the message ‘END WITH ERROR’ will appear.

If the battery is not disconnected within an hour after the message ‘CHARGER FINISHED’ appears, a new maintenance charging process is automatically started, as indicated by the message ‘START TRICKLE’. The display also shows the value of the maintenance-charging capacity TCAP (trickle charge capacity) instead of CCAP during this process. Since the value of TCAP is not stored, the value of CCAP determined during the prior charging process can be called up by pressing the pushbutton.

If the overtemperature function is triggered during the charging process (via the NTC sensor), the program is suspended and the display reads ‘OVERTEMPERATURE’. The program resumes after about 15 minutes, with the displayed message ‘CONTINUE PROGRAM’.

If the program is interrupted due to a mains power failure or switching off the charger, all settings and values are saved. Program execution will continue correctly once mains power has been restored, with the message ‘CONTINUE PROGRAM’ displayed. However, this is only true if the connected battery contains at least four cells and the power outage lasts at least 20 seconds. If the battery contains fewer than four cells, the charger will respond to the power interruption with the message ‘ADJUST: CHARGE’, and the program will have to be manually restarted.

OPERATING TIPS

If the red LED (D6, ‘wrong polarity’) lights up when the battery is connected, the battery has either been connected with the incorrect polarity or it is deeply discharged. With incorrect polarity the message ‘NO ACCU TO SERVE’ remains visible, and you must reverse the battery connections. If on the other hand the message ‘ADJUST: CHARGE’ is displayed, you can proceed with the charging process just as with a battery that is not deeply discharged (ie, for which the red LED does not light).

If the red LED starts to blink when the charging process begins (‘START CHARGING’), there is a protection diode built into the battery or battery pack. The battery must be connected directly to the charger (without the diode).

Program modes

CHARGE

The battery is charged once using a standard fast charge process.

CYCLE

The battery is charged, discharged and then recharged.

ALIVE

The battery is charged, discharged, recharged and again discharged. If the capacity measured during the second discharge is greater than that for the first discharge, the charge/discharge cycle is repeated. This process ends with a final charge process after at most six such cycles, or when there is no difference between successive capacity values.

If the battery has built-in overtemperature protection in the form of a bimetallic contact, the charge current will be interrupted if the overtemperature protection is activated. The charger will then display ‘NO ACCU TO SERVE’. If you do nothing in this situation, the contact will close once the battery has cooled down, and the charger will continue with the charging process. In spite of this interruption, the battery will be fully loaded in the CHARGE program, even if the bimetallic contact is activated multiple times. However, the CCAP display will be reset each time charging is interrupted, so that the value displayed at the end of the process will show only the loaded capacity since the last interruption.

The settings for the number of cells and the battery type must not be changed during operation! These settings may fundamentally only be changed when no battery is connected to the charger. If the charging process is unintentionally started with incorrect battery type or cell number settings, the battery must be **immediately disconnected**, and it may be reconnected only after the settings have been corrected.

Due to the high charging currents, normal plastic battery holders are not at all suitable — the typical spiral spring contact wire will quickly become red hot. Individual cells can only be charged in special battery holders designed for high currents (such as Conrad Electronics part number 51 28 77-01). With battery packs (10 cells maximum, minimum cell size AA), these contact problems do not exist, but you should be sure to use short connecting leads with adequate cross-sectional area (at least 1 mm^2).

Charging is best performed at normal room temperature (20° C), in which case the maximum battery temperature will be 45° C. High and low temperatures should be avoided; the absolute limits are 0° C and 40° C. Cold batteries must be warmed up before being charged, and you should also let the charger warm up before use if it has been stored at a low temperature.

A bit of caution is necessary when charging the smallest-sized cell (AA or mignon). **In general, the nominal capacity must be greater than 700 mAh**. To be on the safe side, you should check the battery temperature during the first several minutes when charging these small batteries for the first time. If the (discharged) battery quickly becomes hot at the start of the process, you should stop charging, since it is evidently not suited to fast charging due to excessive internal resistance. Such a battery should ideally be discarded right away, as should a battery which the charger rejects with the ‘END WITH ERROR’ message. However, please remember that cadmium is a highly poisonous substance, so that such batteries should be properly disposed of in an environmentally safe and responsible manner (contact your local council for information on battery disposal).

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